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Chapter Fifty

ECONOMIC ANALYSIS

50-1.0 GENERAL

The material presented in this chapter is generally intended to provide a methodology to evaluate the cost effectiveness of various safety improvement measures at specific locations.

For most projects, the designer is responsible for ensuring that the design of the project reflects a cost-effective expenditure of the available construction funds. This typically applies to the design of individual elements (e.g., roadway width, intersections, traffic signals, bridge widths and culvert designs). The cost-effective evaluation, for most projects, will be based on the judgment and subjective analysis of the design engineer. Occasionally, a design may warrant an analytical cost-effective evaluation. This might include, for example, a safety improvement project which will be extremely expensive or a 3R project which does not meet the criteria in Chapter Fifty-five. Section 50-2.0 discusses the Department's cost-effectiveness procedures.

Value engineering is an important, creative management tool used by the Department to optimize expenditures for highways and transportation facilities. The Department's value engineering approach is to use a team of individuals from various disciplines who review a project to ensure that it meets the desired objectives. Section 50-3.0 discusses INDOT's value engineering program.

50-2.0 COST-EFFECTIVE ANALYSES

50-2.01 General

The criteria in this *Manual* reflect general cost-effective considerations and are applicable to a wide range of conditions. However, because of the need to develop design criteria for wide-spread application, they must inherently assume typical benefits and typical costs that would normally be encountered in the selection and design of a project. What is actually encountered for a specific project or site may vary widely in terms of expected benefits and expected costs. It is therefore appropriate to consider the cost-effectiveness of applying the normal design criteria to individual projects and sites.

In the vast majority of cases, the cost-effective analysis will be conducted by the application of good engineering judgment. A rough estimate of construction and right-of-way costs is usually available. The designer has likely evaluated the projected traffic volumes, accident history and the project impacts on right-of-way, the environment and utility relocation. When the designer evaluates the likely benefits and costs of the proposed improvement, it is often obvious whether or not a design element under consideration is cost effective. In most cases this approach is the most practical in the interest of time. Therefore, engineering judgment will most often be used to conduct the cost-effective analysis.

In some cases, it may be warranted to conduct an analytical cost-effective evaluation. Several overall approaches can be used. The following sections discuss the basic types of cost-effective methodologies used by INDOT. For additional information on cost-effective methodologies, the user should review NCHRP Synthesis 142 *Methods of Cost-Effectiveness Analysis for Highway Projects*.

The users of any cost-effective methodology should recognize their limitations. These include:

1. The research data to establish critical relationships (e.g., an accident-reduction factor for flattening a vertical curve) may have questionable validity. The research may have made assumptions which are not universally applicable or several research studies may have yielded conflicting results. In some cases, there may be no data available to establish a critical relationship.

2. A cost-effective methodology may require significant amounts of data, and it may require considerable effort to perform.

3. Cost-effective studies can only consider those impacts which are quantifiable and which can be assigned a realistic monetary value. It cannot realistically incorporate the impacts of such factors as general design consistency, aesthetics, land values and uses, access, driver convenience and comfort, social ramifications and environmental consequences.

For these reasons, the results of a cost-effective analysis should only serve as a tool to the decision maker. Despite its analytical approach, there is nonetheless a great deal of subjectivity in the analysis. The final decision must place the results in proper perspective when considering the limitations of the cost-effective methodology.

50-2.02 User Benefit/Cost Analysis

This approach estimates the total user benefits and costs for a project as a whole or for an individual design element within a project. The methodology typically considers user benefits such as savings in vehicular operation costs, reduced driving time and reduced accidents. It typically considers direct project costs such as preliminary engineering, construction, right-of-way and maintenance. The objective is to compare overall benefits to overall costs to determine the economic feasibility of the proposed project or improvement to a specific design element. The comparison may be made by several economic techniques including present worth, benefit/cost ratio, rate of return or payback period.

Many cost-effective methodologies have been developed and many references exist which address user benefit/cost analyses. For most projects, the standard reference is the AASHTO publication *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*. The basic approach in this publication can be summarized as follows:

1. Select Cost Factors. The *Manual* provides highway user cost data for a base year of 1975. The user of the methodology must select multipliers to convert these data to the year under study.

2. Select Economic Study Model. A method to measure the cash outward and inward flows in equivalent dollars by use of a compound interest must be selected. INDOT has selected a discount rate of 4% to calculate present values. An analysis period (e.g., twenty years for new construction) must also be selected (see Section 50-2.03).

3. Estimate Project Costs. These include construction, right-of-way and maintenance costs.

4. Calculate Unit User Costs. The user costs, as a function of traffic characteristics and highway geometry, should be estimated for the alternative designs including the "do-nothing" alternative. User costs include vehicular operating cost, travel time, accident costs and fares.

5. Calculate User Benefits. The benefits for savings in vehicular operating costs, travel time, accident costs and fares should be estimated.

6. Convert to Annual User Benefits. It is usually necessary to convert all benefits to an annual amount.

7. Estimate Residual (Salvage) Value. At the end of a facility's or design element's service life, some value will likely remain. This value should be estimated and its worth included in the methodology to offset project costs.

8. Determine Present Values. The stream of user benefits and user costs over the design service life must be converted to a present value for comparison between the two.

50-2.03 Safety Benefits Based on Accident History

Accident history is usually the best indicator of future accident experience. Therefore, if the data is available and if valid, it is possible to calculate with some precision the cost-effectiveness of a proposed highway safety countermeasure. This approach is applicable to any assessment of the safety cost-effectiveness of a design element intended to reduce the frequency and severity of accidents, assuming the pertinent information is available. Because accident history can only be obtained from existing facilities, the procedures presented in the following sections are generally only used for safety improvement projects and 3R safety enhancements. Section 55-8.0 provides a discussion on how to analyze the accident data.

The controlling factor in this analysis is the benefit to cost ratio (B/C). When the B/C ratio is less than one, the proposed improvement is generally not economically prudent. When the B/C ratio is greater than one, the improvement is typically economically prudent. When the B/C ratio is less than but very close to one, then the secondary benefits resulting from the proposed improvement should be analyzed before abandoning the proposed improvement.

The following sections present INDOT's procedure for evaluating the safety benefits of a project improvement based on accident history.

50-2.03(01) Definitions

1. Equivalent Uniform Annual Benefit (EUAB). The projected annual dollar savings amortized over the service life of the improvement. This savings is based on accident reduction and other related cost savings.

2. Equivalent Uniform Annual Cost (EUAC). The projected annual cost amortized over the service life of the improvement. This cost is based on the initial cost, annual maintenance cost and the terminal (salvage) value of the improvement.

3. Net Annual Benefit (NAB). The difference between the equivalent uniform annual benefit and the equivalent uniform annual cost.

4. Capital Recovery Factor (CRF). The factor used to determine the annual cost with interest to recover the capital investment during the expected service life of the improvement for an

equal payment series.

5. Present Worth Factor (PWF). The factor used to determine the present day value of the projected economic benefits during the expected service life of the improvement. The present worth factor for single payment (PWF_{SP}) is used when determining the present day worth of the terminal value of the improvement. The present worth factor for equal payment series (PWF_{EPS}) is used when determining the present day value of the annual maintenance costs.

6. Service Life. The time period that the improvement can reasonably be expected to impact accident experience. The expected service life should reflect this time period and is not necessarily the physical life of the improvement.

7. Accident Reduction Factor (ARF). The expected percent reduction in accidents based on the type of improvement.

8. Accident Projection Factor (APF). The factor used to project the number of accidents in a given year. It is assumed to be equal to the factor used to project the increase in ADT. Accidents are assumed to increase at the same rate as the ADT.

50-2.03(02) Criteria and Constants

The following criteria and constants should be used in computing B/C ratios. Any deviation from these criteria or constants should be documented in the project files and, where necessary, an informational copy should be furnished to FHWA. The designer should consider the following:

1. Accident Costs. To evaluate projects on the same basis, benefits should be computed with the accident cost values in Figure 50-2A, Accident Cost Per Accident ($).

2. Service Life. Figure 50-2B shows service lives of various improvements. Cost and benefits should be based on these time periods.

3. Interest Rate. For INDOT projects, an interest rate of 4% should be used. Figure 50-2C, 4% Interest Factors for Annual Compounding Interest, provides the present worth and capital recovery factors for a 4% interest rate.

4. ADT and Accident Projection. The designer should assume a 2% increase in ADT and accidents per year over the previous year, unless better data or method of projection is available.

5. Accident Reduction Benefits. INDOT is currently using ARF's developed by the State of Missouri. These factors are presented in Section 50-2.03(05); see Figure 50-2G, Missouri Accident Reduction Factors). The ARF should be applied to the total number of accidents, regardless of the number of people or vehicles involved, when calculating accident reduction benefits. For example:

   a. In the case of a two-car property damage only, use one (1) times the ARF (from Figure 50-2G) times \$3,000 (the accident cost from Figure 50-2A, Accident Cost Per Accident (\$)).

   b. In the case of a two-car accident where one car is property damage only and two personal injuries occur in the other car, use one (1) times the ARF (from Figure 50-2G) times \$37,000 (the accident cost from Figure 50-2A).

   For improvements that involve multiple alternates, Equation 50-2.1 should be used to calculate the total percent accident reduction for each type of accident:

$$ARP_t = ARP_1 + \frac{(100 - ARP_1)}{100} ARP_2 + \left[\frac{(100 - ARP_1)}{100}\right]\left[\frac{(100 - ARP_2)}{100}\right] ARP_3 \cdots$$

(Equation 50-2.1)

   Where:

   ARP_t = total percent accident reduction for multiple improvements

   ARP_1 = the largest percentage reduction in accidents of any of the improvements

   ARP_2 = the second largest percent reduction in accidents of any one of the improvements

   ARP_3 = the third largest percentage reduction in accidents of any of the improvements

   For more information on how to determine accident reduction factors, the user should review the Institute of Transportation Engineers publication, *Selecting and Making Highway Safety Improvements, a Self Instructional Text TTC-440.*

6. Secondary Benefits. Secondary benefits, such as improved capacity or other economic benefits, will not be included in the final computed B/C ratio of the selected alternate solution. Secondary benefits may be used in the B/C computational ratios of the alternate improvements studied in determining the selection of the preferred alternate but should not be used for the final B/C ratio.

7. Equivalent Uniform Annual Benefit (EUAB) and Equivalent Uniform Annual Cost (EUAC).

A summary of the calculations required to determine EUAB, EUAC, and the B/C ratio are shown in Section 50-2.03(03). Example calculations for determining B/C ratios are shown in Section 50-2.03(04).

50-2.03(03) Summary of Steps to Determine the Benefit/Cost Ratio and Net Annual Benefit

The following presents a step-by-step procedure which can be used to compute the B/C ratio and the NAB:

1. Collect accident data and identify accident pattern (see Section 55-8.0).

2. Identify the proposed safety improvement (e.g., flatten horizontal or vertical curves, widen roadway or bridge width, add exclusive left-turn lanes, provide traffic signals).

3. Determine the expected service life of the proposed improvement from Figure 50-2B, Service Lives for Various Projects.

4. Estimate the construction costs and expected annual maintenance costs.

5. Assuming that the accident data will parallel the ADT, estimate accident reduction for each severity class and for each year of the service life of the improvement as follows:

   $$AR = N_a \ x \ ARF \ x \ APF_2 \qquad \text{(Equation 50-2.2)}$$

   Where:

   AR = Accident reduction by year of service life
   N_a = Number of accidents (from accident data)
   ARF = Accident reduction factor (from existing records, judgment or Figure 50-2G)
   APF_2 = Accident projection factor

6. Assign values to accident reductions using data from ARF in Figure 50-2G, Missouri Accident Reduction Factors. Compute the accident reduction benefits as follows:

   $$Accident \ Reduction \ Benefits = AR \ x \ Accident \ Cost \qquad \text{(Equation 50-2.3)}$$

   The result of this step is the gross dollar figure for the total annual benefits for each year of the service life of each improvement.

7. Estimate secondary benefits, wherever possible, and include them in the gross benefit figure

but do not include these in the final B/C computation of the selected alternate.

8. Convert gross benefits from Step 6 above to the EUAB as follows:

   a. Adjust the benefits to the present-day values by multiplying each year's total benefit, from Step 6 above, by the present worth factor for that year from Figure 50-2C, 4% Interest Factors for Annual Compounding Interest.

   b. Add up all of these adjusted benefits.

   c. Multiply the total of the adjusted benefits by the CRF from Figure 50-2C for the last year of the improvement's service life.

   d. The formula for the above steps is as follows:

$$EUAB = CRF \ x \ (summation \ of \ yearly \ adjusted \ benefits) \qquad \text{(Equation 50-2.4)}$$

9. Convert the gross costs to the EUAC as follows:

   a. Multiply the annual maintenance cost by the present worth factor for equal payment series for the last year of the improvement's service life to determine the cumulative maintenance cost.

   b. Add the initial cost to the total of the cumulative maintenance costs.

   c. Multiply the terminal value by the present worth factor for single payment for the improvement's last service year and subtract that amount from the result of Step c.

   d. Multiply the result of Step d by the CRF for the improvement's last service year.

   e. The formula for the above steps is as follows:

$$EUAC = CRF \ [\ I_c + (\ M_{ac} \ x \ PWF_{EPS} \ ) - T \ (\ PWF_{SP} \ )] \qquad \text{(Equation 50-2.5)}$$

Where:

CRF	=	Capital recovery factor for the last year of the improvement's service life
I_c	=	Initial cost
M_{ac}	=	Annual maintenance cost
PWF	=	Present worth factor
PWF_{EPS}	=	Present worth factor (equal payment series)

PWF_{SP}	=	Present worth factor (single payment)
T	=	Terminal value

10. Calculate the B/C ratio by dividing the EUAB by the EUAC as follows:

$$B/C = \frac{EUAB}{EUAC_5} \qquad \text{(Equation 50-2.6)}$$

11. Calculate the NAB by subtracting the EUAC from the EUAB as follows:

$$NAB = EUAB - EUAC_6 \qquad \text{(Equation 50-2.7)}$$

50-2.03(04) Example Calculations for Benefit/Cost Ratio and Net Annual Benefit

The following are two examples for determining the B/C ratio and the NAB.

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<u>Example 50-2.1</u>

Given: Urban Collector/S.R. 62
Non-freeway 3R Project
Horizontal curve which meets the criteria in Section 55-4.03, but has a history of accidents as shown in Figure 50-2D, Accident Summary (Example 50-2.1).

Problem: Determine if realignment of the horizontal curve will be cost effective

Solution: The following steps from Section 50-2.03(03) apply:

Step 1: Collect accident data. The accident data is provided in Figure 50-2D.

Step 2: Identify the proposed safety improvement. The selected improvement is to realign the horizontal curve.

Step 3: Determine the service life of improvement. From Figure 50-2B, Service Lives for Various Projects, the expected service life for a horizontal alignment change is 20 years.

Step 4: Estimate initial construction and annual maintenance costs. From similar projects, the construction costs are estimated to be $750,000 with annual maintenance after realignment to be $3,000. After 20 years, the terminal (salvage) value is expected to be $20,000.

Step 5: Estimate the assumed accident reduction for each accident type and for each year of service life. The following will apply.

a. From Figure 50-2G, the ARF is 50%.

b. The ARF is assumed to be 2% per year; see Item #4 in Section 50-2.03(02) and Column 2 in Figure 50-2E, Accident Reduction Benefits (Example 50-2.1).

c. From Figure 50-2D, the average annual PDO accidents is 5.66 and average annual F/I accidents is 2.33.

d. Using Equation 50-2.2, Columns 3 & 4 of Figure 50-2E present the expected number of PDO and F/I accidents reduced.

Step 6: Compute accident reduction benefits. The following will apply; see Figure 50-2E:

a. Column 5. Determine the benefits of the reduced number of PDO accidents by multiplying the value in Column #3 by $3,000 (from Figure 50-2A, Accident Cost Per Accident ($)), using Equation 50-2.3.

b. Column 6. Determine the benefits of the reduced number of F/I accidents by multiplying the value in Column #4 by $37,000 (from Figure 50-2A) using Equation 50-2.3.

c. Column 7. Determine total benefit of the reduced number of accidents by adding Columns 5 and 6.

d. Column 8. Determine the present worth factor from Figure 50-2C, 4% Interest Factors for Annual Compounding Interest.

e. Column 9. Determine the present worth of the benefits from the reduced number of accidents by multiplying Column 7 by Column 8.

f. Total. Determine the total yearly benefits by summing the values in Column 9. The total yearly benefits for this realignment example is $846,958.

Step 7: Estimate the secondary benefits. For this example, there are no secondary benefits.

Step 8: Convert gross benefit from Step 6 to EUAB. The CRF factor from Figure 50-2C for 20 years is 0.0736. Using Equation 50-2.4:

$$EUAB = 0.0736 \times \$846{,}958 = \$62{,}336$$

Step 9: Convert gross costs to EUAC. Using Equation 50-2.5:

$$EUAC = (0.0736) \times [\$750{,}000 + \$3{,}000(13.5903) - \$20{,}000(0.4564)] = \$57{,}529$$

Where:

CRF	=	Capital recovery factor for the last year of the improvement's service life = 0.0736 @20 years (from Figure 50-2C)
I_c	=	Initial cost = \$750,000
PWF_{EPS}	=	Present worth factor for equal payment series = 13.5903 @20 years (from Figure 50-2C)
PWF_{SP}	=	Present worth factor for single payment series = 0.4564 @20 years (from Figure 50-2C)
M_{ac}	=	Annual maintenance cost = \$3,000
T	=	Terminal (salvage) value = \$20,000

Step 10: Calculate the B/C ratio. Using Equation 50-2.6:

$$B/C\ Ratio = \frac{EUAB}{EUAC} = \frac{\$62{,}336}{\$57{,}529} = 1.0836$$

Step 11: Calculate the NAB. Using Equation 50-2.7:

$$NAB = EUAB - EUAC = \$62{,}336 - \$57{,}529 = \$4{,}807$$

Comments:

1. The NAB is a positive value as expected because the B/C ratio is greater than 1. This means that, if the proposed improvement were constructed, the projected annual benefits would be \$4,807.

2. Because the B/C ratio is greater than one, this project would be cost effective to construct.

Example 50-2.2

Given: Urban Collector/S.R. 62

Non-freeway 3R Project

Horizontal curve which meets the criteria in Section 55-4.03, but has a history of accidents as shown in Figure 50-2D, Accident Summary (Example 50-2.1).

Problem: Determine if improving the superelevation at the horizontal curve will be cost-effective.

Solution: The following steps from Section 50-2.03(03) apply.

Step 1: Collect accident data. The accident data is provided in Figure 50-2D.

Step 2: Identify the proposed safety improvement. The selected improvement is to improve the superelevation on the horizontal curve.

Step 3: Determine the service life of improvement. From Figure 50-2B, Service Lives for Various Projects, the expected service life for horizontal alignment change is 20 years.

Step 4: Estimate initial construction and annual maintenance costs. From similar projects, the construction costs are estimated to be $750,000 with annual maintenance after realignment to be $3,000. After 20 years, the terminal (salvage) value is expected to be $20,000.

Step 5: Estimate the assumed accident reduction for each accident type and for each year of service life. The following will apply.

a. From Figure 50-2G, Missouri Accident Reduction Factors, the ARF is 50%. However, because the selected improvement would still have restricted horizontal geometry, an ARF=30% is assumed for these computations.

b. The APF is assumed to be 2% per year; see Item 4 in Section 50-2.03(02) and Column 2 in Figure 50-2F.

c. From Figure 50-2D, the average annual PDO accidents is 5.66 and average annual F/I accidents is 2.33.

d. Using Equation 50-2.2, Columns 3 and 4 of Figure 50-2F, Accident Reduction Benefits (Example 50-2.2), present the expected number of PDO and F/I accidents reduced

Step 6: Compute accident reduction benefits. The following will apply; see Figure 50-2F.

a. Column 5. Determine the benefits of the reduced number of PDO accidents by multiplying the value in Column 3 by $3,000 (from Figure 50-2A) using Equation 50-2.3.

b. Column 6. Determine the benefits of the reduced number of F/I accidents by multiplying the value in Column 4 by $37,000 (from Figure 50-2A) using Equation 50-2.3.

c. Column 7. Determine total benefit of the reduced number of accidents by adding Columns 5 and 6.

d. Column 8. Determine the present worth factor from Figure 50-2C, 4% Interest Factors for Annual Compounding Interest.

e. Column 9. Determine the present worth of the benefits from the reduced number of accidents by multiplying Column 7 by Column 8.

f. Total. Determine the total yearly benefits by summing the values in Column 9. The total yearly benefit for this example is $508,175.

Step 7: Estimate the secondary benefits. For this example, there are no secondary benefits.

Step 8: Convert gross benefit from Step 6 to EUAB. The CRF factor from Figure 50-2C for 20 years is 0.0736. Using Equation 50-2.4, the EUAB is as follows:

EUAB = 0.0736 x $508,175 = $37,402

Step 9: Convert gross costs to EUAC. Using Equation 50-2.5, the EUAB is as follows:

EUAC = (0.0736) x [$750,000 + $3,000 (13.5903) - $20,000 (0.4564)] = $57,529

Where:

CRF = Capital recovery factor for the last year of the improvement's service life = 0.0736 @20 years (from Figure 50-2C)

I_c	=	Initial cost = \$750,000
PWF_{EPS}	=	Present worth factor for equal payment series = 13.5903 @20 years (from Figure 50-2C)
PWF_{SP}	=	Present worth factor for single payment series = 0.4564 @20 years (from Figure 50-2C)
M_{ac}	=	Annual maintenance cost = \$3,000
T	=	Terminal (salvage) value = \$20,000

Step 10: Calculate the B/C ratio using Equation 50-2.6 as follows:

$$B/C\ Ratio = \frac{EUAB}{EUAC} = \frac{\$37,402}{\$57,529} = 0.6501$$

Step 11: Calculate the NAB using Equation 50-2.7 as follows:

$$NAB = EUAB - EUAC = \$37,402 - \$57,529 = -\$20,127$$

Comments:

1. The NAB is a negative value as expected because the B/C ratio is less than 1. This means that, if the proposed improvement were constructed, the projected annual cost would be \$20,127.

2. Because the B/C ratio is considerably less than one, it will not be economically prudent to construct the proposed pavement.

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50-2.03(05) Accident Reduction Factors

The Department is presently using the accident reduction factors developed by the State of Missouri. These factors are provided in Figure 50-2G.

50-2.04 Safety Benefits Based on Accident Potential (Run-off-the-Road Accidents)

It is unusual for a roadside site to have a sufficiently high-accident experience to estimate safety benefits based on accident history. They usually occur at random locations along the highway roadside. However, run-off-the-road accidents in total represent a high proportion of highway accidents. Therefore, roadside hazard improvements may be warranted even if a particular site has never experienced a hazard.

Appendix A of the AASHTO *Roadside Design Guide* presents a methodology to evaluate the cost-effectiveness of a roadside safety improvement. This methodology will assess the potential for a given hazard to be struck based on pertinent traffic, highway and hazard characteristics and will allow for the calculation of the cost effectiveness of the alternative countermeasures. It can be used to evaluate individual sites or to evaluate roadside safety for highway segments (e.g., 1 to 2 km in length). There is an inherent realization in this approach that a certain number of those hazardous locations where a treatment is deemed to be cost effective will never experience an accident, and a certain number of those hazardous locations where a treatment is deemed to be not cost effective will, in fact, experience an accident.

The AASHTO methodology establishes the following possible countermeasures in order of desirability:

1. Remove the roadside hazard.

2. Laterally relocate the hazard to a location where the potential for being struck is acceptable.

3. Reduce the severity of the hazard by making it breakaway or by making it traversable.

4. Shield the hazard with guardrail or crash cushion.

5. Do nothing; i.e., leave the hazard unshielded.

The step-by-step procedure allows the determination of which countermeasure is the most cost effective.

Chapter Forty-nine presents the Department's warrants for guardrail and other safety appurtenances. Appendix A of the AASHTO *Roadside Design Guide* in conjunction with the Department input data (e.g., accident costs) should be used to determine the appropriate warrant application. Section 49-10.0 provides a step-by-step guide on how to use ROADSIDE (i.e., the ROADSIDE Computer Software Program for Appendix A).

50-3.0 VALUE ENGINEERING

50-3.01 General

Value Engineering (VE) can be defined as a systematic application of recognized techniques, by a multi-disciplinary team(s) which identifies the function of a product or service; establishes a worth for that function; and provides alternative ways to accomplish the necessary function reliably, at the lowest overall cost, through the use of creative techniques. VE is not merely a method of cost cutting but a methodology to review alternatives and to suggest choices that still provide a reasonable product without reducing its quality. Value engineering is a proven effective tool for both product improvement and design enhancement. VE can substantially improve design and cost-effectiveness of projects, facilities, operations, procedures and other areas of the transportation program.

VE uses the team approach to review all aspects of the project — design, procurement, construction, operation and maintenance. Typical VE teams are made up of 5 to 7 individuals with a variety of expertise to study the major problem areas anticipated within the project (e.g., traffic, right-of-way, structures, soils, materials, construction, design, maintenance). Due to cost and time constraints, the VE team will normally only review 20% of the project elements which account for approximately 80% of a project's total cost. For the greatest benefit, VE should be implemented as early as practical in a project development. Figure 50-3A, VE Potential During Life of a Project (Conceptual), illustrates the benefit of how implementing VE early in the project development can provide the greatest savings.

50-3.02 INDOT's Application

Not every project warrants the review of a value engineering team. For most projects, the Department relies on the designer to implement the VE approach in his or her design. Large projects or projects with special design concerns are prime candidates for review by a value engineering team. Project selection for VE reviews are typically determined during the project's preliminary engineering study stage.

50-3.03 References

For more detailed information on value engineering techniques and procedures, the user is referred to the following publications:

1. *Value Engineering for Highways*, FHWA, Revised October 1983.

2. *AASHTO Guidelines for Value Engineering*, 1987, AASHTO.

3. *Value Engineering in Preconstruction and Construction*, NCHRP Synthesis 78, TRB, September 1981.